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1.0 Introduction/Site Description

Frontier Environmental Services, Inc. (Frontier) under contract to Walsh Environmental Scientists and Engineers, Inc. (Walsh) has performed geotechnical and spatial analysis of the spent oil shale pile and associated features located in the Anvil Points Facility as part of the objectives of the Engineering Evaluation/Cost Analysis (EE/CA) for the U.S. Department of the Interior, Bureau of Land Management (BLM).

The Anvil Points facility is within the Naval Oil Shale Reserve 3 approximately 7 miles west of Rifle, Colorado (Section 17, T6S, R94W, 6^{th} PM). The spent oil shale pile is located on the steep slope just west of West Sharrard Gulch. The pile consists of processed (retorted) shale and raw shale fines. The pile is approximately 900 feet long and 150 feet at its highest point. The surface of the shale pile has a slope of approximately 1.4H:1V and contains several areas of material sloughing. Construction of the pile appears to have occurred by dumping the material from the top of the slope with no compactive effort applied to the material.

Three impoundments located just to the east and south of the foot of the spent oil shale pile were also part of the spatial analysis. Borings were drilled in these ponds for environmental samples and to determine the depths of the waste materials. These ponds were constructed to capture sediment runoff from the pile and to dispose of materials generated and used in processing the oil shale. The locations of the impoundments are shown on Figure 1.

2.0 Work Performed

Frontier Environmental Services, Inc. performed a topographic survey of the spent oil shale pile and the surrounding area during the month of November 2003. The survey was used to develop a site map for the spent oil shale pile, the impoundments below the pile and the surrounding area. A geotechnical investigation was performed to determine the

engineering characteristics of the materials in the pile and to determine the stability of those materials. The information obtained in the geotechnical investigation was also used in conjunction with the topographic survey to develop cross sections for use in the stability analysis and to better estimate the volume of the waste materials located in the pile. The following sections explain in detail the work performed.

3.0 Topographic Survey and Volume Calculations

The topographic survey was performed by Inter-Mountain Engineering during the week of November 3, 2003. The survey was based on control points that were set by the Bureau of Land Management prior to November 3, 2003. A GPS unit capable of accuracy within $1/100^{th}$ of a foot was used to perform the topographic survey. Measurements were taken to define the oil shale pile slopes and grade changes and to define the topography of the existing native slopes approximately 100 feet from the pile in all directions where feasible. Approximately 1050 measurement points were taken on the pile and in the general area of the pile and the former impoundments located to the east and south of the pile.

A site map was developed based on the survey data and is shown as Figure 1. An estimate of the original ground surface (prior to placement of the waste) was determined from the data obtained in the geotechnical investigation. The volume of the spent oil shale pile was then estimated to be approximately 108,000 cubic yards by determining the volume between the estimated native ground surface and the surveyed surface of the existing pile. The estimate of the native ground surface is based on limited information and does not accurately represent the entire area. It is Frontier's experience that an additional 20% of this volume could be present due to irregularities in the native surface. The estimated volume of the waste pile based on this assumption is approximately 130,000 cubic yards.

4.0 Drilling and Sampling Methods for the Geotechnical Investigation

The geotechnical investigation of the processed oil shale pile was conducted on December 16 and 17, 2003. Case Davis, P.E., with Frontier, was the Engineer on site to perform the sampling and logging for the geotechnical investigation and Stan Spencer with Walsh Environmental was on site to obtain samples for environmental analysis.

A total of 4 borings were drilled to depths of 45 to 60.5 feet below the existing surface. A tracked rig, approximately equivalent to a CME 45, was used to drill the borings. The borings were drilled with 4-inch solid stem augers or 6-inch hollow stem augers. Boring logs indicate sample depths and types, penetration resistance measurements, and material descriptions. The boring logs also indicate the depths to the native ground surface ranged from 28 to 55 feet. The boring logs can be found in the Slope Stability Analysis Report in Appendix A. Groundwater was not encountered in any of the borings.

Samples of the subsurface materials were taken at selected intervals using both a ring-barrel sampler and a split spoon sampler. Bulk samples representative of the entire boring were also taken from the cuttings brought to the surface by the auger. Penetration resistance measurements were obtained by driving the ring barrel and split-spoon samplers into the subsurface materials with a 140-pound hammer falling 30 inches. The "blow counts" provide insight into the nature of the subsurface material with respect to consistency, hardness and relative density of the material. Samples obtained with the ring barrel sampler were then sent to the laboratory for analysis.

A total of 15 ring barrel samples and 4 bulk samples were collected from the borings. The ring barrel samples were collected at intervals shown on the boring logs. The intervals were chosen to represent the entire pile profile and to determine engineering properties of the processed shale and the underlying native shale materials. Selected samples were analyzed for the following engineering properties:

- Water Content

- Dry Density
- Grain Size
- Plasticity Index
- Direct Shear Strength

The processed oil shale material had an average dry density of 80 pounds per cubic foot (pcf) with moisture contents ranging from 4 to 23 percent (averaging 17 percent). The internal angle of friction (phi-angle) derived from the direct shear strength tests is approximately 25 degrees. The complete results of the geotechnical tests are in the Slope Stability Analyses report included in Appendix A.

4.1 Investigation of the Adjacent Impoundments

Borings were also drilled in the impoundments located just below the spent oil shale pile for environmental analysis of the sub soils. These borings were not sampled for geotechnical engineering parameters. Three borings were taken in the Relic pond and two borings were taken in each of the Upper Impoundment and the Lower Impoundment. Locations of the impoundments and the borings are shown in Figure 1. Volumes of processed shale materials in the impoundments were estimated based on approximate area of the pond surface and the average thickness of the materials.

Borings drilled in the Relic pond indicated a layer of cover soil that was 2.5 to 3.5 feet thick. A densely packed layer of very fine, black processed shale was encountered below the cover soil to a depth of approximately 8.5 feet. A plastic liner was encountered below the processed shale. One of the borings in the Relic pond was located on the edge of the pond with the liner only 6 inches below the surface. The estimated volume of processed shale material present in the Relic pond is approximately 1500 cubic yards. Approximately 500 cubic yards of native shale material was used to cover the processed shale in the pond.

Borings drilled in the Upper Impoundment indicated a layer of cover soil approximately 1 foot thick that covered a densely packed layer of very fine, black processed shale to a depth of approximately 4 to 4.5 feet. No plastic liner was visible in the upper impoundment. The estimated volume of processed shale material present in the Upper Impoundment is approximately 1800 cubic yards with an additional 500 cubic yards of native shale material covering the processed shale.

Borings drilled in the Lower Impoundment indicated that no processed shale was present to depths of 5 to 8 feet below ground surface.

5.0 Slope Stability Analysis Summary

Frontier Environmental Services, Inc. employed Terracon to analyze the geotechnical soil samples and to provide slope stability analyses of the processed oil shale pile. Terracon's slope stability analyses report is included in Appendix A. The following is a brief summary of the findings of the Slope Stability Analyses.

The processed shale pile currently has a factor of safety against shear failure of less than 1.0. Minimum factors of safety for long term slope stability typically range from 1.3 to 1.5. The low factor of safety indicates that the spent oil shale pile is unstable in its current configuration.

An approximate slope configuration of 2:1 (H:V) of compacted material would raise the factor of safety against failure to 1.3 and a slope configuration of 3:1 (H:V) of un-compacted material would raise the factor of safety against failure to 1.4.

Immediate corrective actions that are needed to limit sloughing of the stockpiled material include improving the surface drainage to redirect surface water away from the top of the slope and the pile face and improving the drainage at the bottom of the slope to prevent water from collecting at the base of the slope or infiltrating the toe of the slope.

These recommendations are based on the assumption that no groundwater is present in the pile. Saturation of the pile, even in the recommended configurations, would most likely result in slope failure.

6.0 Summary and Comments

The Anvil Points processed oil shale pile is approximately 900 feet long and 150 feet high and consists of processed (retorted) oil shale fines that were deposited from the top of a steep slope and were not compacted after dumping. A topographic survey was performed on the processed shale pile for the purpose of determining the site spatial characteristics and to aid in estimating the volume of the pile. A geotechnical investigation was also performed to determine the stability of the existing slope and to aid in estimating the volume of the pile.

The volume of the pile is estimated to be approximately 130,000 cubic yards of waste material. The factor of safety for slope stability of the pile is less than 1.0 which is below the accepted factor of safety ranging from 1.3 to 1.5. The slope will need to be reconfigured to obtain long term stability.